A

STEM DISEASE OF TEA

CAUSED BY

***Nectria Cinnabarina* (Tode) Fr.**

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A tea bush attacked by *Nectria*.

The same bush after treatment.

A STEM DISEASE OF TEA CAUSED BY *NECTRIA CINNABARINA* (TODE) Fr.

Disease associated with certain trees.

For many years it had been noticed that the tea in the neighbourhood of certain trees, notably Utis (*Alnus nepalensis*) and Umphi (*Pyrularia edulis*), was frequently unhealthy and it was thought locally that the trees in question secreted some sort of plant poison. It was apparent that the illhealth of the bushes could not in many cases be ascribed to anything connected with the roots of the Umphi or the Utis trees as often fairly deep ditches separated the tea from the trees in question. Nor was the damage confined to the area under the shade or the drip of the trees but seemed to be determined to some extent in the case of fresh outbreaks by the direction of the wind. On some gardens it was found that *Erythrina Spp.* were centres of infection.

On investigation it was found that the unhealthy tea was attacked by a fungus, a species of *Nectria*. For a long time however the connection between the fungus on the tea and the trees associated with its occurrence was obscure. It was eventually discovered that *the same fungus attacked the flowering shoots of* the trees in question.

Damage.

The damage done by the disease was considerable, especially on some gardens where Utis trees had been planted as wind-breaks.

Symptoms of the disease.

Tea bushes attacked by this fungus become moribund but rarely die right out. The stems die back and the new shoots which arise lower down are generally thin and weakly. In a few cases healthy shoots break away from the collar but these quickly become moribund. The general appearance of the bushes is similar to that of tea very badly attacked by red rust. In a few cases the plants form callosities on the stems in an attempt to repair the damage done by the fungus. These are not however characteristic of the particular disease as they are caused by many agencies.

The fungus which causes the disease.

The fungus which causes the disease is either Nectria cinnabarina (Tode) Fr. or a very nearly allied species. The fungus attacks the bark of woody stems and the growing layers (between the bark and the wood) and spreads from them down the medullary rays into the pith. The wood is not at first attacked. The fungus does not kill the growing layers at once but gradually starves the infected stems which become moribund and after some months in that state frequently die. The fungus is generally present in the tissues of the plant some distance below the portion obviously diseased. On the death of the shoot, sometimes before, the fruiting stages are produced. These are easily found. They are produced on the bark of the stems. The most noticeable are pink cushions about 1/32 of an inch across which are usually produced in profusion. These are called conidiophores and consist of a mass of fungal hyphae or threads arranged together with their ends outwards. The end of each hypha swells slightly and a wall grows beneath the swelling. The swollen end then becomes detached, forming a spore. These spores are called conidiospores and the cushions in which they are borne, conidiophores. Along with the conidiophores another form of fructification is produced—a number of dark red spherical bodies about of an $\frac{1}{40}-\frac{1}{50}$ inch across. These are produced singly or in groups, sometimes attached to the conidiophores, but more often separately. Examination of these with a lens shows that they each have a small coneshaped aperture. The coneshaped portion collapses slightly in old ones. A more careful examination with a microscope reveals that these bodies are protected by hairy out-growths sometimes minutely roughened. These bodies contain a large number of sausage-shaped sacs each containing eight two-celled spores. The walls of the spores are often minutely striated. These spores measure $10-15 \asymp 5\mu$.* They are called ascospores. The sausage-shaped sacs are asci (Sing. ascus) and the spherical cases perithecia (Sing perithecium). Still another form of spore is produced. They are long narrow ones measuring $37-60 \asymp 3-3{\cdot}5\mu$,* and are called fusarium spores from their

* $\mu = \frac{1}{1000}$ of a millimeter.

A wind-break of Utis (*Alnus nepalensis*)

shape. They are sometimes found on loose tufts of hyphae round about the perithecia and conidiophores.

Life history of the fungus.

The fungus was grown in pure culture from all three kinds of spores and also from mycelium found in the wood and bark of infected tea branches.

It was most successful on maize meal agar and cane sugar agar. The colour in all cases was white to pink. The conidiophores appeared in 6—8 days but the perithecia were very much later.

On sterilised tea stems the perithecia formed more quickly. Fusarium spores were produced freely in all the cultures.

Mode of infection.

Innoculations with both mycelium and conidiospores were carried out on tea bushes growing at Tocklai and were successful on wounded shoots but not on undamaged ones. From this it may be infered that the fungus is a wound parasite. It should however be pointed out that the climate of Tocklai is so different from that of Darjeeling that it does not necessarily follow that the fungus cannot infect undamaged shoots there. In any case there would be ample opportunity in either district for the fungus to gain access to the plants, as plucking, of necessity, causes wounds and our experiments at Tocklai prove that such wounds can be infected.

Treatment.

It is necessary first of all to remove trees known to harbour the fungus. This is often a difficult thing but as the spores do not seem to travel very far it only appears to be necessary to remove these trees in the neighbourhood of the tea.

The diseased bushes should be pruned to good wood in the cold weather and sprayed with a fungicide immediately after pruning in order to protect the cuts from possible infection. The prunings should all be burned on the spot at once.

The above treatment has been carried out with good results on various gardens. Tea bushes apparently dead frequently come away well after collar pruning.

Technical description of fungus.

The fungus may be described technically as follows:—

Perithecia measuring 200-400/ᵘ. in diameter; arising usually in groups, sometimes singly, occasionally arising from conidiophores, otherwise on a stroma, usually cushion-shaped; dark red, becoming brown and sometimes black with age, spherical, with a conical ostiole, protected by hairs frequently covered with minute granulations. The asci measuring 47-65.7≍11/ᵘ are cylindrical or club-shaped with slightly attenuated apices, containing eight spores which are usually arranged in two rows, oblong, slightly curved, one-septate, colourless, minutely striated lengthwise, measuring 10-15≍5/ᵘ. Conidiosphores are pink, cushion-shaped, produced singly or in clusters. Conidiospores are 7·5-10≍3-3·75/ᵘ, oval, colourless. Fusarium spores, measuring 37-60≍3-3·5/ᵘ, formed from tufts of mycelium in the neighbourhood of both perithecia and conidiospores, 4-11 septate.

Nectria cinnabarina (Tode) Fr. is described in Saccardo as follows (Saccardo II):—

Peritheciis, caespitosis, confertis, stromate pulviniformi, hemispherico, carnosula, primitus, *conidia secernente, instratis, sphaeroidiis, corrugatis, cinnabarinis demum fuscescente*—expallentibus, ostiolo papiliformi, ascis cylindraceo—subclavatis, apice leviter attenuatis, 60-90≍8-12 octosporis, sporidiis distichis vel submonostichis, oblongatis, utrinque obtusis, rectis vel leviter curvulis, uniseptatis hyalinis 14-16≍5-7)ᵘ, status conidicus Tubercularia vulgaris Tode. Hab in ramis corticatis emortuis arborum et fruticum fere omnium in tota Europa, Ceylon, Siberia, Amer. bor.

Var *levior* Sacc Rel Lib II n 210: peritheciis minus rugosis in Fraxino Salici etc. in Gallia.

Var *Tiliae* Karst Symb. Myc. Fenn. VI p 239, Sporidiis elongatis curvulis, 18-26≍4—5·5 in ramis Tiliae in Fennia.

Var *obscurata* Rehm Ascom n 184. Peritheciis fuscis vel rubro fuscis; ascis 75≍15 sporidiis 20≍7 cum typo.

Nectria Cinnabarina (Tode) Fr. on tea.

The plate shows a tea stem bearing the conidial and perithecial fructifications of the fungus. Beneath this is a drawing of a portion of a conidiophore, bearing spores. Beside this a perithecium is shown—the projecting hairs are marked by minute granulations. Above this is a group of asci with some germinating ascospores. The ascospores are minutely striated. At the top of the plate the fusarium form of fructification is shown. Two of the fusarium spores are connected to spore-like outgrowths.

The fungus is described by Wilson and Seaver in **N. American flora as follows :—**

Stromata, erumpent, tubercular, at first pinkish or yellowish red, becoming darker with age, often brownish and occasionally quite black 1-2/$^\mu$ in diameter and 1-2/$^\mu$ high. Conidiophores 50-100/$^\mu$ long without lateral branches on which the conidia are borne ; conidia 4-6$\asymp$2/$^\mu$ ellipsoid, hyaline ; perithecia springing at first from the base of the stroma, which at maturity is covered by the cespitose clusters of perithecia ; individual perithecia nearly globose, with the ostiolum rather prominent, becoming slightly collapsed, and at first cinnabar red, becoming darker with age, often brown and occasionally black (when withered), roughened externally with coarse granules, 375-400/$^\mu$ in diameter, asci clavate 50-90$\asymp$7-12/$^\mu$ 8 spored ; spores mostly 2-seriate, ellipsoid, elongate, about 3 times as long as broad, with obtuse ends, 1-septate hyaline, mostly a little curved, 12-20$\asymp$4-6 long, paraphyses very delicate.

Seaver who has worked on the fungus in America states that the following are synonyms for the same fungus to which he gives the name *Creonectria purpurea* :—

Tremella purpurea L. Sp., Pl 2 : 1158	A. D. 1753
Sphaeria tremelloides Weigel Obs Bot. 46	„ 1772
Tubercularia vugaris Tode Fungi Meckl 1 : 18	„ 1790
Sphaeria cinnabarina „ „ 219	„ 1791
Cucurbitaria cinnabarina Greville, Scot Fl Crypt 3 : 136 ...	„ 1825
Nectria cinnabarina Fries, Summa Veg Scand 388 ...	„ 1849
„ *Sambuci* Ellis & Evertr. Proc. Acad. Nat. Sci. Phil. 1890 : 246	„ 1891
„ *meliae* Earle, Bull. Torrey Club 25, 364	„ 1898
„ *Russellii* Berk & Br. Grevillea 4 : 45	„ 1875
„ *offuscata* Berk & Curtis 4 : 45	„ 1878
„ *nigrescens* Cooke „ 7 : 50	„ 1878
Sphaeria dematiosa Schw Trans Am Phil Soc. II 4 : 205 1832	„ 1890
„ *celastri* Schw. Fries ; El. Fung. 2 : 81	„ 1827
Nectria purpurea (L) Wilson & Seaver, Jour. Myc.13 : 51 ...	„ 1907 „ 1908

From a study of the various descriptions it would appear that the fungus varies considerably and the difference between the type and our specimens is not sufficient to warrant a new species being made. The markings on the hairs mentioned above do not seem to have been noted by other investigators of *Nectria cinnabarina* but as in our specimens they are not always present they cannot be considered characteristic.

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Indian Tea Association.

A NOTE ON THE VALUE OF DIFFERENT INSECT CONTROL METHODS IN TEA AND AGAINST MOSQUITO BLIGHT IN PARTICULAR

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A NOTE ON THE VALUE OF DIFFERENT INSECT CONTROL METHODS IN TEA, AND AGAINST MOSQUITO BLIGHT IN PARTICULAR.

The problem of insect control is one of considerable antiquity. To take but one instance, familiar to all, Old Testament history informs us of damage done by locust swarms in Egypt in the time of the Pharaohs. Those swarms took place some three to four thousand years ago, and might be supposed to have an interest purely historical, yet we find that as recently as 1915 the phenomenon was repeated. In Part III of this Journal for 1915 will be found a reference to a swarm of the locust *Schistocerca peregrina*, one of the Egyptian forms, which penetrated as far East as Upper Assam, while the following account of a campaign undertaken against this same locust and others, which caused great havoc in Northern Africa and Asia Minor in the same year (1915), will show that there has been no lessening of the activity of these pests since the time of the Pharaohs..

"The anti-locust campaign organised by the author was "conducted by a staff of 14 directors, 72 officers, 2,000 supervisors, "about 11,000 men from the labour battalions and compulsory "levies from the population. In western Anatolia an average of "450,000—500,000 workers were daily employed from March to "May. The Cyprus system of barriers was largely adopted and "about 6,000 tons of eggs and 11,000 tons of locusts were col- "lected. Arsenic and Paris green were tried and suitable baits "were sawdust, chopped lucerne, chopped grass and cowdung, salt "being added to all of these. No practical results were obtained "with fungus diseases or bacterial infections. In the plains the "losses were reduced from 40—50 per cent. to 6—10 percent. For "1917, 250 non-comissioned officers and 2,500 men were detailed "as instructors and 600,000 metres of zinc barriers and 50 tons of "arsenic and Paris green were ordered."

The question not unnaturally arises as to what the science of economic entomology has been doing all this time. The answer to this lies in the fact that until recent years the science of economic

entomology, as such, has been practically non-existent. It was not until a comparatively recent date that it came to be realised that the study of entomology, popularly regarded as a hobby of cranks, could be of any practical utility, and even since this has come to be realised, the innate distrust on the part of the practical man of scientific innovations, on the one hand, and a bigoted tendency on the part of a certain school of biologists to regard applied science as something vastly inferior to pure science, and the exponents of the former as charlatans, on the other hand, have delayed the recognition to which this branch of science was justly entitled.

All this is now being altered.

For some time past certain Governments and large corporations have maintained entomological staffs, and recent discoveries regarding the important part played by insects in regard to diseases of plants, animals, and man have awakened a new interest in this particular branch of research, as is evidenced by a rapidly increasing demand for men trained to the work, to meet which educational bodies are now affording increased facilities for the instruction of students. At the same time it has to be admitted that the science of insect control is as yet in its infancy, and, as is often the case in such circumstances, more is apt to be expected of it than it can as yet perform, and its exponents, being expected to produce immediate results in the field with an insufficiency of experimental data at their command, are often compelled to adopt haphazard methods of control without being able to carry out the detailed investigations which form the necessary groundwork of all real progress.

This sort of thing results in practice outstripping theory, for any measure of success attained by such methods must be largely due to mere good fortune, the result being that the operator is led to handle weapons the proper use of which he does not thoroughly understand, with, often, disastrous results.

The object of this note is to bring prominently before the tea industry the present position with regard to insect control, to discuss the merits and demerits of the various methods generally recommended, and to point out the lines along which modern research is tending to lead us.

The methods which have been adopted from time to time in the endeavour to control insect pests may be considered under several heads.

1.—The primitive method of collecting the insects when they are found to be at work on the plants.

2.—The method of destroying the insects by the use of chemical substances applied to the plant when the insects are at work.

3.—An examination of the life history and habits of the insect, followed by attempts to deal with it by collection, chemicals, or other means, applied at a time when the insect, from the circumstances of its habits or life cycle, is particularly vulnerable, though it may be doing no actual damage at the time.

4.—Attempts to use natural control agencies such as predators and parasites.

5.—Attempts to obviate the necessity for direct control by breeding resistant varieties of plants.

6.—Investigations into the causes which render plants liable to attack by pests, and attempts to treat them in some manner which will render them less liable to suffer.

Collection of ins.....

The collection by hand and destruction of insect pests has doubtless been carried on since agriculture first commenced, and, given a sufficiently small area or a sufficiently large labour force, can be thoroughly efficient. Within the confines of an allotment garden, or in the case of a gregarious insect like the Bunch Caterpillar, which congregates during the day in conspicuous clusters on the stems of the plant, when it occurs on a well-laboured garden, collection by hand can be successfully carried out. Hand collection, however, is a tedious and laborious method, and in the case of damage on a large scale by insects which are not gregarious, and which may perhaps be minute, becomes impossible. Many machines have been devised, ranging from a simple hand-net to large instruments pulled by horses, to increase the efficiency of catching operations, some of which appear to have been efficacious for the particular purpose the designer had in view, but all such methods are cumbrous, and diffi-

cult of adaptation to any change in circumstances, and possess, as a rule, a very low degree of efficiency. Co-operation on the part of all in the affected area, and often an elaborate and expensive organisation, are necessary to attain even a small measure of success, and even in cases where a permanent staff is maintained to supervise the work, and the agriculturists are compelled by legislation to co-operate, the benefit obtained is often hardly commensurate with the time, money, and labour expended. So much is this the case that it is but seldom that collection can be relied upon as a sole means of control, and in large campaigns in which collection is one of the means adopted it is generally combined with some other measure such as poisoning by baits or spraying with insecticides.

The mere collection of the insects, then, cannot be relied upon as a means of control in large scale infestations, though organised collection has a certain value if combined with other methods. There are, however, certain circumstances in which hand collection may be entirely effective, as instanced in the case of the allotment garden and the case of a pest with habits similar to the Bunch Caterpillar. The main factors in successful control by hand collection are close observation of the plants and the application of the method while the pest is present in small numbers only, and, given these, much can be done by this simple method even on a tea garden. One actual occurrence of many which have come to our notice, may be quoted, which will show how very well worth while this method may be. On one bush, on the edge of a garden path, the manager noticed that the leaves were being eaten, and ascertained that small faggot worms were present on the bush. A couple of boys, offered sufficient inducement, cleared that and the surrounding bushes from the pest in one day, and no sign of the insect has been noticed since. The manager had given no thought to the life history of the pest, but, from his promptitude in applying a very simple remedy, had averted what might have been a serious invasion, as every planter acquainted with faggot worms will realise. The young insects were probably the progeny of one female. The female is wingless, and lays her eggs inside the faggot she inhabited as a caterpillar, and dies. The faggot containing the eggs had probably fallen into or alongside the bush from a bundle of firewood carried by a cooly. The caterpillars

travel only very slowly in the young stages, and, by prompt action, all were collected very easily in the restricted area they had invaded. Since the migration of the caterpillar is the only means of distribution of this pest apart from accidental translocation of faggots containing eggs the collection of the insects proved an entirely satisfactory measure.

Many other instances could be cited, but sufficient has been said to show that mere hand collection, in spite of its low degree of efficiency in general, is a method which can often be applied with great success.

The value of hand collection of the insects in the case of mosquito blight is a matter regarding which there is considerably diversity of opinion. From what has been said above regarding the necessity for careful observation and prompt action it will readily be realised that the results obtained may vary considerably according to the stage at which operations are commenced. Cases have been known of a definite increase in outturn by this method, but such cases are the exception. Catching during the early part of the season has, however, a very definite value, if systematically carried out. The rate of development of the tea mosquito varies considerably, so much so that at the quickest rate at which it can develop it can pass through fourteen generations in the year, while the slowest rate of development carries it through four generations in the same period. The only explanation we can offer for the sudden diminution in numbers of the insect towards the end of the season is that the bulk of the insects then present, as would only be natural, are those which have passed through a rapid development, with a consequently decreased vitality. These succumb to the unfavourable conditions, while the comparative few which have developed slowly survive the cold weather and carry on the species. The latter represent the normal infestation, the former the abnormal infestation which occurs, as we believe, owing to the exceptional conditions of a large and favourable food supply, which conditions begin to accrue on the advent of the rains. Now it is obvious that the fewer individuals present at the beginning of the rains, the later in the season will the rapidly breeding forms attain to any given number. Moreover, while it is hopeless to attempt to keep pace with the rapidly breeding forms by

hand catching, there is a certain hope of keeping the insects down before rapid development begins to take place to any great extent. This being so it is well worth while to collect the insects before the time at which the rapid increase in the rate of development commences. In this case however, equally as in the case of large locust campaigns such as is referred to above, adequate organisation and efficient supervision are necessary if any measure of success is to be attained. It is not sufficient to give a band of children a roving commission to collect the insects when the latter have attained such numbers as to force their attention on the garden manager as he does his daily "kamjari." The work should be commenced directly new growth begins to appear on the pruned bushes, whether punctures have been noticed or not. Each child should be given his own lines of bushes, and the garden should be examined for insects as systematically as it is traversed by the plucking women during the season. By this means affected bushes will not be missed and the small amount of growth on the bushes will render the capture of the insects easy.

Destruction of the insects by the application of chemical substances to the bushes during the period of attack.

The short-comings of the method of hand-collection must have become manifest very early in the history of insect control, and since in those days the life histories and transformations of insects were not understood, the destruction of the insects present on the plant would still be the object desired. To this end men's thoughts would naturally turn to the application of some substance to the plant which would either destroy or drive away the insect, and this is what seems to have actually occurred. Moreover, the application of any substance might naturally be supposed to be the more effective the nastier the substance used, and the early history of liquid applications to plants teems with references to mixtures which must have been horrid in the extreme, and probably caused much more irritation to the operator, in many cases, than to the insect.

This method of treatment, demanding, as it did, no special entomological knowledge, being a great saving in labour as compared with hand catching, and possessing a far greater degree of adaptability

to circumstances, grew rapidly in popular favour, and from such small beginnings as the application of cow's urine from a watering can (which would naturally do good on account of its manurial value if for no other reason) has arisen the present system of spraying, with such variations as fumigation, applications of powders, the use of poisoned baits, and the like.

The early investigations on these lines naturally consisted in an examination of the value of different substances, and, when a number of substances possessing killing properties had been discovered, attention was also turned to the devising of efficient machinery for their application. Great strides have been made in this branch of the subject, so much so that it is now possible for the expert to advise with certainty as to the type of insecticide which will prove most effective as a means of controlling any particular pest, and spraying is now one of the most universally accepted methods of control. So long as a vast number of substances of possible value remained untried, this method of control received (and still receives) a great measure of attention, but as research has increased our knowledge of the properties of substances formerly untested, without, as yet, leading to the discovery of any substance of unquestionable merit, and as practical experience has shown that this method, like the last, has serious limitations, the belief of many in the value of chemical applications as an ultimate means of insect control is being shaken. Spraying is of undoubted value, in many cases, as a palliative, but it now seems certain that this method cannot be anticipated to give complete control. Indeed, many of the standard remedies of the present day are amongst the oldest of the substances tried. Thus, whale-oil solutions have been in use against scale insects since 1802, tobacco decoctions since 1822, lime-sulphur since 1833, and copper solutions since 1807. Arsenicals were first used somewhere about 1860. Some of the more modern insecticides consist of mixtures of complex organic compounds, and certain of them show a remarkable degree of efficiency in certain circumstances, but their use is greatly restricted by their high cost.

There may be, in practice, such difficulties in the way of spraying as to render it entirely impracticable, and these difficulties are apt to be greater in the case of perrenial crops than in the case of crops

sown and reaped annually, for in the latter case arrangements can generally be made, when planting the crop, which will facilitate subsequent spraying operations. In the case of a perennial crop such arrangements can be made at infrequent intervals, when, for some reason or other, the area has to be replanted. Some plants, also, can be adapted for spraying more conveniently than others. Thus, hops can be grown, and is grown, in practice, in such a way as to render the results of spraying dependent entirely upon the efficiency of the spray fluid used. By planting the rows a given distance apart, training the vines on trellises which have the laths fixed at given angles, and drawing between the lines a spraying machine on which the nozzles are fixed in the appropriate places and at the appropriate angles, it is possible to ensure that the whole of the surface of the hop vine shall be covered with spray fluid.

Not all crops, however, can be adapted to spraying operations so conveniently as this, and tea is a case in point.

In the case of tea there are many points to be considered before spraying is attempted. The first, one of the most important, is the fact that tea is grown for the young and tender leaf, and not for its fruit, and that the leaf is plucked at intervals which may be only several days apart. This puts out of court almost entirely all substances which are poisonous to man, and restricts the choice of insecticides very considerably. The second is the enormous areas, planted in the past, at varying distances apart, intersected, in many cases, with numerous drains, and shade trees; containing bushes of all shapes and sizes, which touch one another, so that passage between them is difficult, for the greater part of the season, which also are so heavily clothed with foliage that efficient spraying of the inside of the bush is a matter of extreme difficulty; and often poorly furnished with communicating roads, whose utility is greatly circumscribed by the flimsy nature of the bridges. Such circumstances greatly limit the variety of mechanical appliances which can be utilised, so much so that the knapsack type of machine is practically the only one which can be used with any degree of efficiency.

Another point is the question of water supply. The satisfactory spraying of 400 acres of tea would necessitate the supply of 40,000 gallons of water.

A fourth consideration is the quantity of the labour available. Under favourable circumstances one man might carry water for two spraying men, who might cover 1 acre in a day. This would mean the employment of 120 men per day to spray 400 acres in ten days. This number of men would be a considerable drain on the labour force of a garden of that acreage, but since it is a desideratum in spraying for insects to cover the ground quickly there would be a loss in efficiency if the numbers were reduced. Again, cooly labour can hardly be relied upon to do such work thoroughly except under close supervision, which introduces another cause of loss in efficiency.

Another handicap which has to be considered when the adoption of a spraying method is advocated is that due to rainfall. Tea flushes during the rainy season, and any substance which is to stick to the foliage for any length of time must of necessity possess adhesive properties above the average. It may be remarked here that the drawbacks due to this cause are less in the case of a contact insecticide which must come into contact with the insect to kill it, than in the case of a poison insecticide, which is applied to the plant to be eaten by the insect.

All the above causes militate greatly against the complete success of spraying operations in tea, but in spite of this there are certain spray fluids which have a definite value, and certain circumstances in which spray materials may be used not, be it understood, as a means of control, but as a palliative.

Setting aside the requirements of the mycologist, there are three solutions which can be recommended for use in tea. One of these is useful for a variety of purposes, the other two have a limited application.

The first is lime-sulphur solution.

This solution is best prepared in the form of a stock solution according to the following formula :—

Quicklime	...	20 lbs.
Sulphur	...	$22\frac{1}{2}$,,
Water	...	50 gallons.

The lime should be put into a drum and slaked by adding water gradually. When it is fully slaked, water to about 30 gallons should be added, and the whole brought to the boil. When it is boiling the sulphur should be added gradually, stirring vigorously the while, and *boiling* water added to make 50 gallons. Boil for an hour longer, keeping the volume at 50 gallons by adding *boiling* water.

On cooling this gives the stock solution, which may be strained if necessary.

For use on tea in leaf, or on nursery plants, this solution may be *diluted to 1 in 8 or 10* with water, and at this strength is a useful spray for use against tea aphis, red spider and other mites, and, under certain circumstances, tea mosquito, and it also possesses a certain value against scale insects and thrips.

In the cold weather the insecticide may be used at greater strengths, and then, in addition to the above, fulfils many of the functions of soda washes. At that time of year it may be used as strong as one part of stock solution to four of water on high-pruned tea, and one part to one of water on low-pruned tea. On the latter it may be applied with a brush or swab.

The second solution is soda-wash.

For the preparation of this solution either of the three following formulæ may be used :—

(1)	Caustic Soda (98 %)	...	2	lbs.
	Water ...	...	10	gallons.
(2)	Washing soda ...	...	7	lbs.
	Quicklime ...	...	2	,,
	Water ...	...	10	gallons.
(3)	Soda ash ...	...	2½	lbs.
	Quicklime ...	...	2	,,
	Water ...	...	10	gallons.

To make the first solution the caustic soda should be added to the water a little at a time with careful stirring. The water should not be added to the caustic soda, as great heat will be developed.

To make solutions (2) and (3) the lime is slaked and thoroughly mixed with part of the water. The washing soda or soda ash is dissolved in the rest of the water, and the two solutions mixed.

The proportion of lime is sometimes increased in practice in order that a white coating may be left on the bushes and the work more easily checked.

Soda washes should only be used in the cold weather on old hide-bound wood. Used on young wood, they make it slow in coming away. These solutions soften the bark, thus making it less liable to attack by bark-eaters, kill off the lichens and mosses which shelter scale insects, pupæ of thrips, hibernating red spider and the like, interfere to a certain extent with termites, and also kill many of the insects and mites with which they come into contact. Not only so, but buds, which may contain eggs of the tea mosquito, are destroyed, and the eggs with them. Strong lime-sulphur, as mentioned above, performs many of these functions, though not quite to so great a degree, but when once the old frames have been properly cleaned by the application of a soda-wash, lime-sulphur should be all that is necessary.

The third solution which has proved itself of value in tea is a proprietory insecticide which was found to be very useful against thrips. This insecticide is known as XEX, and is made by a firm at Dusseldorf in Switzerland. Lime-sulphur, again, though not so efficient, is a good substitute, and possesses the advantage of cheapness.

Many may wonder why, with such a number of different insecticides on the market, the number recommended for use in tea should be so limited. The reason is not that there are not other efficient insecticides, but that there are none other which give equal results for the same outlay. Not only so, but the efficiency with which insecticides can be applied under the conditions obtaining in tea is so low that in practice it becomes the limiting factor in the efficiency of the insecticide. It is the number of insects left to carry on which controls the amount of damage done after the spray has been applied, and in tea faulty application is

the rule, even when the strictest supervision is exercised, as anyone who will take the trouble to spray a line of tea, and then examine the bushes he has sprayed, will speedily realise.

The possibilities attending the use of the two insecticides of limited application have been sufficiently outlined above, and further discussion of the possibilities and limitations of spraying may be confined to lime-sulphur. This insecticide acts on copper, and must be used in spraying machines made of brass, so that the choice of machines, which it has been shown above is practically limited to knapsack sprayers, must be limited still further to knapsack sprayers made of brass. Even brass is slowly attacked by the solution so that a further essential is that all machines should be thoroughly cleaned after use. Red spider may be sprayed with a considerable degree of efficiency, and since lime-sulphur, properly applied, will kill 100 per cent. of the insects, the results are directly proportional to the degree of thoroughness with which the operation is carried out. Tea mosquito is a different proposition. Lime-sulphur will kill both adults and young, if it comes properly into contact with them when they are in active movement, but owing to their high degree of resistance, combined with their activity, it cannot always be relied on, even when carefully applied to the bushes. If a tea mosquito, adult or young, be covered with the spray when at rest, it is able to clean it all off and suffer little or no inconvenience. The respiratory orifices can be closed by a strong sphincter muscle, and this apparently takes place so rapidly that the insecticide is unable to take effect. This applies, not only to lime-sulphur, but to substances as strong in their action as formalin, and it has been found that the youngest stages of the insect can resist a concentration of formalin solution double that which destroys the flush completely. Should the insect, however, be in flight or in active movement when struck by the insecticide, respiration seems to continue for a little, and the insect is killed. Young forms of the insect may be killed owing to a peculiarity in their habits. When the bush is disturbed in any way they run down the stem and take shelter at a node. Spraying creates a considerable disturbance, and they make for the nodes. The spray fluid runs off the leaf down the stem and collects in a drop at the node, and the young insect is

entangled in a drop from which it cannot escape owing to the force of surface tension, and is killed. Thus, in spraying against tea mosquito, it is necessary to soak the bushes thoroughly, and it is obvious that the results achieved may vary considerably according as the majority of the insects happen to be in the adult or young stages at the time the spray fluid is applied. Further, the insecticide does not affect the eggs, and subsequent applications are necessary, not only to kill some of the insects which escaped before, but to kill those which have emerged from eggs present when the spray was previously applied. Lime-sulphur kills only by contact, so that unharmed insects can still feed on the bush with impunity, and once the fumes which are undoubtedly produced have dispersed the insects can feed and oviposit on the bushes as before.

Thus the effectiveness of lime-sulphur, although it is known to be fatal to the insect, is limited in practice, though it has a distinct value as a palliative. Used to soak bushes on which insects have been found early in the season, or, at intervals of not more than eight days, on small areas which are affected, it is a practical proposition, but large-scale spraying is out of the question.

Fumigation, again, is but a palliative. The choice of gases is greatly restricted owing to the greater degree of susceptibility of the plants than of the insects, and the presence of cooly lines here and there on the estate. The activity of the insects enables the adults to fly ahead of the gases as their concentration increases to an uncomfortable degree. Eggs cannot be killed by this method. The vagaries of the wind render its operation uncertain. Fumigation, like spraying, is limited in its application, needs to be repeated at intervals, and is of value only in exceptional circumstances. Like spraying, it has been tried with good effect, but can hardly be recommended for general use on a large scale.

Attempts at control by taking advantage of some peculiarity in the life history of the pest, not necessarily at the time when damage is being done.

As knowledge regarding the peculiarities of insects increased, and experience of insect pests accumulated, it began to be realised

that the time at which damage was being done was not necessarily that at which control could be most efficiently or most economically effected. Attention was then directed to investigations into the life histories, habits, and peculiarities of insect pests, and this step marked a distinct advance in the science of insect control. It led, not only to a more efficient application of the empirical methods of hand-collection and spraying, but also to the development of new methods of still greater value, more particularly methods consisting in a modification of agricultural practice to meet the requirements of the particular case. Such methods of insect control have a value which can hardly be over-estimated. Being based on a knowledge of the habits of the insect, and formulated in a logical manner, their possibilities and limitations can be accurately estimated. Being merely modifications of the agricultural practices already in existence, they involve the use of weapons which are always at hand, and the use of which is thoroughly understood by the agriculturists and operators. They can be made a feature of the ordinary routine work of an estate without any appreciable disorganisation of the necessary cultural work, and can thus be used not only as means for cure or palliation, but as preventive measures, which are far more satisfactory.

Such control methods have already become a matter of routine on some tea gardens. Combining the collection of the chrysalides of caterpillar pests with the cold weather forking is a case in point. At that time none of the pests are at work on the bushes, but by taking advantage of their habit of spending the cold weather in the inactive pupal condition just below the surface of the soil it is possible, without any disturbance of the ordinary garden operations, to destroy enormous numbers and prevent serious attack during the following season. In this way the primitive method of hand-collection is given an increased degree of efficiency. During the plucking season, also, since most of the insects pass through several generations, there are certain times at which they are in the inactive pupal condition in the ground. Such times are marked by the disappearance of the full-fed caterpillars from the bushes. The regulation of the hoeing or forking cultivation so that affected sections receive a hoe at these times will result in the destruction of

large numbers of the insects, and reduce the damage done by succeeding broods.

Spray fluids can likewise be used more efficiently when the habits of the pest are taken into consideration. Red spider, for instance, hibernates, amongst other places, in crevices in the bark of the bushes. The application of strong lime-sulphur, after pruning thus, amongst other things, accounts for the death of many of the mites which would in the ordinary way be there to commence an attack next season.

Control methods of this type are of such value that in some cases the existing agricultural practice exerts a sufficient control without any special modification being necessary. This occurs in tea in the case of the leaf-eating beetles. A new clearance will often be found to be riddled by these insects, but after the tea has been brought into full cultivation for a year or two they will be found to be reduced to a negligible number, the continual cultivation having brought about the destruction of the delicate grubs, which live just below the surface of the soil, and feed on the roots of surface growing plants.

Many other means which take advantage of some peculiarity in the habits of the pest are adopted under different circumstances of crop and pest. In general farming, for example, it is sometimes possible to exert a certain control by a proper adjustment of the order of rotation of the various crops grown on the same area in successive years, thereby destroying insects which are selective feeders by giving them unsuitable food for a year or two. Another method sometimes adopted is to grow a "catch-crop," that is a crop of some plant which will be attacked by the insects and can then be destroyed with the insects on it. The "catch-crop" used may even be a crop of an early variety of the particular plant which is being cultivated. In other cases advantage is taken of the attraction of light or aromatic substances for the insects to destroy them in large numbers, a homely instance of the latter being familiar to all in the shape of the domestic fly-bottle.

Control by Parasites and Predators.

As time progressed, and the circumstances affecting the bionomics of insects became known in greater detail, it came to be realised that insects are subject to disease, form food for insects of predatory habit, and act as hosts to parasites which eventually cause their destruction. Further research showed that any particular species might have its specific parasites, be subject to specific diseases, or form a staple article of diet for some particular species of predatory insect, and when it was found that certain species which attained the status of pests in one country were apparently kept under control by predators or parasites in another a revolution in methods of insect control was anticipated which, though much has been done in connection with the subject since, has, up to the present, been hardly realised. At first sight, it may seem a comparatively simple proposition to transfer a predator or parasite from one country to another, and it may also be supposed that when liberated in a situation in which it can obtain an abundance of its staple food, it must of necessity increase in numbers with considerable rapidity, with the result of gradually bringing the pest concerned under control. Experience has proved, however, that the difficulties connected with this method of control are enormous. Even when the obstacles in the way of successful transportation of the parasite from one part of the world to the other have been successfully surmounted the difficulties connected with the problem are not by any means overcome. It may be that some circumstance connected with the life-history of the parasite, undiscovered before importation, is not fulfilled by the environment to which it has been transferred. Climatic conditions may be wrong, shelter and shade may not be such as it requires, some plant, the nectar of whose flowers is essential to the prolongation of the life of the adult sufficiently to allow of oviposition taking place, may be absent, or may not flower quite at the right time. Some indigenous parasite may prove to be a far more efficient parasite of the introduced parasite than the latter is of the pest it is desired to control, or, under the new conditions, the parasite may take to attacking some other insect whose destruction is not being aimed at. Again, the life-cycle of the pest may differ sufficiently, at one place, from

that of the same species at the other place, to render it unsuitable as a host.

Such are a few illustrations of the kind of difficulties which have to be surmounted in this branch of the work, quoted to show that the question of control by the use of natural agencies such as predators and parasites opens up a field of enquiry so vast as almost to be comparable with the remaining branches of economic entomology added together. The very reason for the prosecution of these enquiries, namely, the unsatisfactory nature of the other methods of insect control, renders it impossible to assist the parasites in their struggle against enemies and adverse conditions. Hence it is that so little has been heard of the work since it was boomed in the press on the realisation of its possibilities some years ago. A certain amount has been done. Parasites and predators have been introduced and established in some places, and are assisting to some extent in the fight against the particular pest concerned, but in the majority of cases, so far, it has been found that the problem of encouraging the parasite in the field is as difficult as, if not more so than, that of controlling the pest. Once the parasites have been liberated they must be left to work out their own salvation, for control of the parasite becomes as difficult in the one direction as control of the pest in the other. The question of control of tea pests by such means has received a certain amount of attention, and in practice it has been found that one pest of tea is very effectually controlled by a parasitic fly, this pest being the gelatine bug, some eighty per cent of the cocoons of which have been found, on occasion, to be parasitised. Red spider and tea aphis are both devoured in enormous numbers by various ladybirds and the larvae of lace-wing flies. Tea mosquito is preyed upon by spiders and carnivorous insects like the praying mantis, but does not seem to form the staple food of any of them, other insects, especially small flies, being taken with even greater avidity. A mermithid worm has been found to parasitise the insect, but nowhere to a greater extent than two per cent, and since it has been found to occur in tea already wherever tea mosquito is to be found, there is no question of introducing and establishing it where it does not already exist. Altogether,

the prospects of this means of control proving of value in tea in the near future are far from hopeful.

Legislation.—This brings us to the end of our discussion of the methods which are attempted to obtain control by means calculated to compass the direct destruction of the insects. There remains for discussion a further method, that of obviating the necessity for their destruction by breeding resistant varieties of plants or by attempts to treat the plants in such a way as to render them immune from attack. Before turning to this branch of the subject brief reference may be made to the fact that in most countries legislation is now being brought to bear on the matter. Pest laws are being enacted, have been, in some places, in force for a considerable time, which are calculated not only to prevent the introduction of pests, or their extension from province to province, by strict inspection of all consignments of plants, but also to increase the efficiency with which the present imperfect control methods can be carried out by compelling those concerned to take such steps as are considered necessary by experts authorised to command action and enforce penalties. Such legislation may be permanent, or may be enacted temporarily as considered necessary by the advisory experts, and there is no doubt that under such conditions the efficiency with which control can be carried out is considerably increased. It can hardly be said that such legislation would be of benefit to tea so far as entomology is concerned, though collaboration between neighbours might often be of benefit, but a mycologist might have a very different tale to tell.

Resistant Varieties of Plants.

It has been found, in many instances, that certain varieties of a particular plant are more subject to attack by a particular insect pest than others. This has been taken advantage of in many cases with success, and has led to attempts to breed resistant varieties where none previously existed. More work has been done on these lines in connection with fungus diseases than in connection with insect pests, but such a remarkable degree of success has been attained in some instances as to cause many to look

forward to such methods with some degree of confidence. The question of breeding varieties of tea has so far received little or no attention, and the slow rate of propagation of the plant would demand many years of work before any distinction between varieties could even be recognised. Differences in liability to attack by different insects are, however, noticeable in the field between different varieties of tea, and there is no doubt that, given identical conditions, some delicate light-leaved varieties are more liable to attack by a pest such as red spider than more hardy dark-leaved varieties, and that China varieties may succumb to the attack of an insect such as tea mosquito more readily than indigenous sorts. There is, however, a tendency for these differences to be exaggerated owing to emphasis by environmental conditions, and since no variety of tea has yet been found to breed perfectly true, the degree of liability to attack is apt to differ with specimens of the same variety. Present prospects of control in tea lie rather in the direction of rendering existing bushes immune than in breeding resistant varieties.

Investigation into the causes which render plants liable to attack by pests.

The idea of producing immunity of plants from insect attack cannot be said to be entirely new. Realisation of the fact that different varieties of a given plant show differing degrees of liability to attack naturally led to a consideration of the question as to how those differences were brought about. For some time it was thought that such properties must be intimately connected with the life processes of the plant, and bound up with the vital forces, inherent in living organisms, which are transmitted from generation to generation by heredity, but which cannot be introduced into organisms in which they are not already present.

Closer observation, however, has shown that not only do different varieties show differing degrees of susceptibility to insect attack, and not only do different individuals of a given variety likewise differ amongst themselves, but that any given individual may differ, from time to time, in the degree to which it suffers from attack owing to changes in the circumstances of its environment.

This latter fact was not discovered for a long time, for the reason that such differences were in former days ascribed to variation in the number of insects present, and since the absence of the insects at the time of making any particular observation could not be taken as a criterion long and patient examination of a large number of cases was necessary before the variations could be justifiably ascribed to differences in the plant. In the case of certain pests of tea, however, as well as in the case of certain pests of a few other plants, it has been definitely ascertained that the amount of damage being done may be out of all proportion to the number of insects present. Such variation can only be ascribed to variation in the degree of resistance to attack possessed by the bush. When this fact is considered in conjunction with some of the recent work on experimental biology by which it has been shown that many so-called vital phenomena are nothing more nor less than reactions to external stimuli, and can be induced artificially by the application of the requisite stimulus, it is not difficult to realise how the thoughtful observer would be led to anticipate the possibility of the production of immunity in plants by artificial means.

This is a stage which has at length been reached in the study of insect control. It is a stage which marks a distinct advance beyond anything which has as yet been suggested for many reasons, and it is an aspect of the problem which we desire to impress upon the attention of the tea industry, from the possibilities it opens up in connection with the control of mosquito blight. The advantages of such a means of control may be considered.

Such a method would afford complete control, so far as crop production is concerned. When plants are immune from attack the damage done by the insects is *nil.*

Such a method involves treatment of the plant, which is a fixed organism, and any treatment adopted can not only be perfectly controlled, but the results can be accurately estimated.

Treatment of the plant involves the application of methods which can be readily comprehended by anyone connected with agriculture, and, once a satisfactory treatment is evolved, the

application of the method can be efficiently carried out without the necessity for continual expert outside assistance.

Lastly, should the method devised involve a repetition of treatments at intervals, they are likely to be such as can be incorporated in the ordinary routine work of an estate, and capable of being efficiently carried out with a minimum of supervision.

We feel justified in laying emphasis on this aspect of the problem, although no satisfactory scheme for practical application has yet been formulated, from the encouraging indications of the feasibility of such methods of control which have already been observed, not only on an experimental scale, but in the field.

It is not necessary, in this place, to recapitulate the numerous observations which led to the gradual evolution of this idea. Suffice it to say that we have found that differences in the degree of resistance to attack appear to be the rule in the field, not only in the case of different bushes, but in the case of a given bush under different circumstances of environment; that the insects, while they flourish on leaf from bushes which show a high degree of susceptibility to attack, are unable, not only to flourish, but to maintain the vital activities necessary to existence, on leaf from bushes known to resist attack ; that these differences in degree of resistance to attack are connected with the proportion of potash to phosphoric acid in the leaf; that these differences in the composition of the leaf may be caused to exist, in bushes planted in the same soil, by differences in the system of agricultural practice adopted, and are accompanied by corresponding variations in the degree of liability to attack; that in cases when the bushes are found to be throwing off an attack in the field this phenomenon is accompanied by a marked increase in the proportion of potash as compared with phosphoric acid ; and that direct injection of potash into the bush does not only produce immunity, but causes bushes which have already succumbed to the attack in such degree as to be entirely unproductive to throw off the pest entirely and give copious flushes so long as the supply of potash is maintained.

Thus complete control, in the case of an individual bush, can be exerted by this means, a form of control which is effective owing to the production in the bush of immunity from attack.

The problem of the application of the method to large-scale treatment, however, has been found to be somewhat complicated, and has necessitated a more intensive study of soil problems, and their relation to plant behaviour, which cannot as yet be considered to have advanced beyond the preliminary stages. At first it was thought that the production of resistance to attack might be possible by the application of potash in some manurial form to the soil, and a slight success obtained in a preliminary experiment gave colour to the idea, which, however, was somewhat discounted when subsequent experiments showed that the same manurial application produced different results on different soils, in a manner which could not be satisfactorily explained. It then became evident that more than one factor is involved, as regards the soil, in connection with the question of production of conditions favourable to the imparting of an increased degree of resistance to attack to the bush, and attention has had to be directed towards an enquiry into soil conditions in general, and more particularly those which appear to influence bushes one way or the other as regards their degree of liability to attack by the tea mosquito, an enquiry which is still proceeding.

It has been found, however, that certain bad forms of cultivation, such as hoeing in the rain and thereby puddling the soil, defective drainage, pans at different depths, and so on, do influence the bushes for the worse, and the enormous value of the improved methods of tea culture which have been adopted in recent years is strikingly shown in the accompanying curve showing the average outturn per acre, from 1896 to 1919, of gardens in the Duars. This curve shows, in no uncertain manner, the bad mosquito years which have been experienced from time to time, in 1902, 1908, 1910-12, 1914, and 1918. It shows more than that, however. The curve shows a steady rise since the beginning of this century, a time at about which the history of tea shows that interest was beginning to be taken in the development of more scientific methods of crop production, as was evidenced, among other things, by the appointment of a scientific officer, and the inauguration of a scientific department. Since that time this interest has been maintained, methods of cultivation, etc., have steadily improved, and

of the work done, with the result that, not only has outturn increased, but that in a bad mosquito year such as 1914 an outturn of more than 7½ maunds an acre is obtained as contrasted with a a little over 6½ maunds in the good year of 1899. Mosquito blight is still considered by some to be as bad as it ever was, and there is indeed no doubt of this, but it is obvious that in the Duars as a whole this attention to improved methods has resulted in imparting to the bushes the power to make more growth before succumbing entirely to the attack of the pest.

This result should give confidence in any method based on the principle of increasing the resistance of the bush to attack, and it also shows that although no immediate benefit may be seen from the result of such work, it gradually tells as time goes on.

Thus, while our manuring experiments with potash gave no immediate results in certain cases, we have since found that the results often begin to show after two or three years. Instances are beginning to accumulate, also, of cases in which the continued application of potash to the soil is resulting in a gradual diminution of the degree of liability to attack. In other cases, where defective drainage was believed to be one of the principal factors, attention to this matter is resulting in a gradual lessening of the damage done by the pest. All this, taken in conjunction with the experimental observations referred to above, goes to show that there is a distinct hope of effective control by some such means as are now being advocated, a hope far greater than is offered by any of the methods for control previously tried. We are encouraged in this hope by the fact that, in the case of crops more favourably circumstanced than tea, complete control has been possible by an application of the principles of this method. In Africa it has been found that wheat becomes more liable to certain diseases when grown in a soil containing excessive nitrogen. If, in a crop rotation scheme, the order of cropping be beans, wheat, and flax, the wheat suffers from the excess of nitrogen fixed in the soil by the leguminous crop which preceded it. If, however, the crop of flax, which takes an enormous quantity of nitrogen

from the soil, be grown first, and the wheat after, the latter remains comparatively immune from disease.

Thus we would advocate that planters should experiment a little more along these lines of recent development, prepared to obtain benefit by slow degrees, rather than that they should continue the endeavour to press such methods as spraying, etc., beyond the limits of which they are capable. The older methods of attacking the insects direct are of undoubted value within certain limits, which have been outlined above, but beyond these limits it is a better, and a sounder, policy, to follow the more up-to-date method of attempting to control the pest by proper treatment of the plant, by improving the drainage system of the estate, by discrimination in the use of agricultural implements, and by judicious application of the proper substances to the soil. It is not not yet possible to lay down any definite scheme which can be guaranteed to result in certain and immediate success over large areas, but we feel that much time, labour, and money is being expended throughout tea in forlorn attempts to deal with tea mosquito on large areas by methods which cannot be expected to give results commensurate with the outlay, and which would be much better expended in experiment on lines calculated to increase the resistance of the plant to attack.